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Turner

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(54) **BACKING FOR PRE-PREG MATERIAL**

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C08J 5/24	(2006.01)
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B29C 59/10	(2006.01)
B29C 65/00	(2006.01)
B29C 70/32	(2006.01)
B32B 38/00	(2006.01)
B32B 37/10	(2006.01)

(52) **U.S. Cl.**

CPC ***B29C 37/0075*** (2013.01); ***B29C 70/30*** (2013.01); ***B29C 70/342*** (2013.01); ***B32B 37/003*** (2013.01); ***C08J 5/24*** (2013.01); *B29C 35/02* (2013.01); *B29C 59/10* (2013.01); *B29C 66/028* (2013.01); *B29C 66/721* (2013.01); *B29C 70/32* (2013.01); *B32B 38/0008* (2013.01); *B32B 2037/109* (2013.01); *B32B 2305/076* (2013.01); *B32B 2309/68* (2013.01); *B32B 2310/14* (2013.01)

(58) **Field of Classification Search**

USPC 156/247, 266, 267, 270, 272.6, 286, 156/300, 299, 308.2, 307.1, 307.7, 87, 229, 156/73.1, 238, 258, 265, 302, 285, 486; 264/257, 258, 319

See application file for complete search history.

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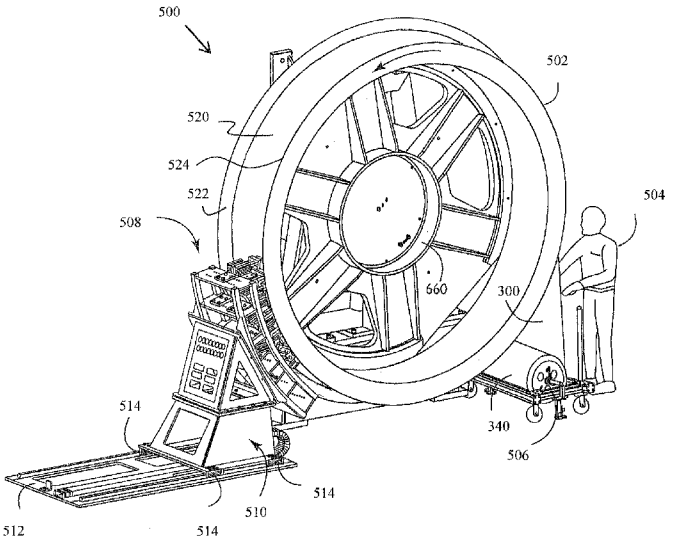
(57) **ABSTRACT**

A method of preparing pre-impregnated (pre-preg) material is provided. The method comprises treating a first surface of a backing with a corona discharge to enhance surface adhesion and applying the pre-preg material to the treated surface of the backing to form a pre-preg material with backing.

29 Claims, 5 Drawing Sheets



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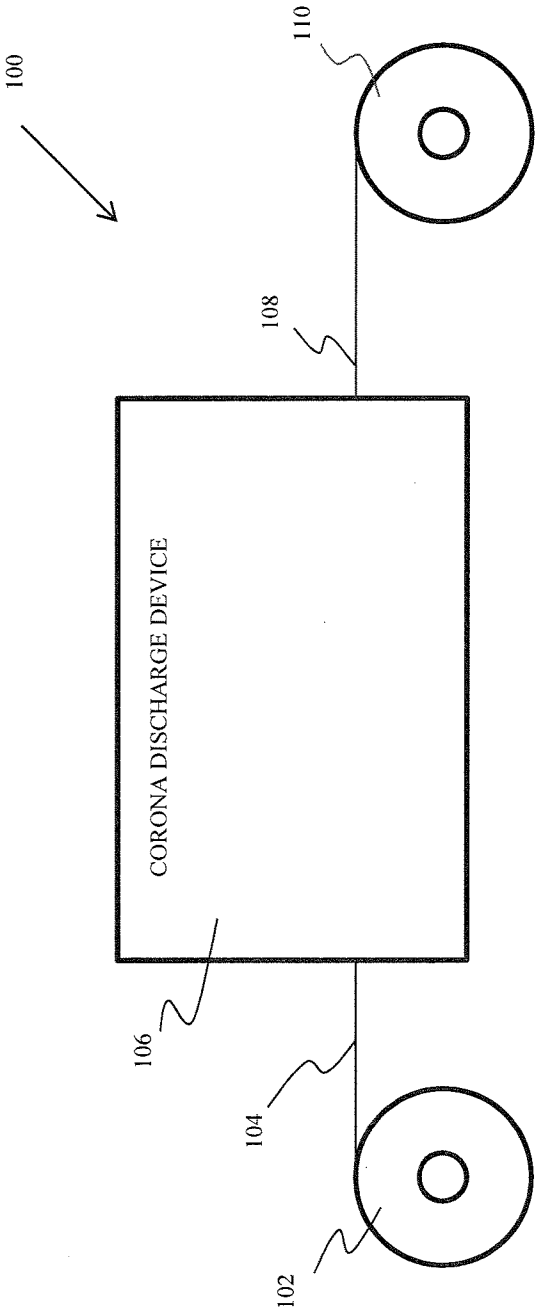

FIG. 1

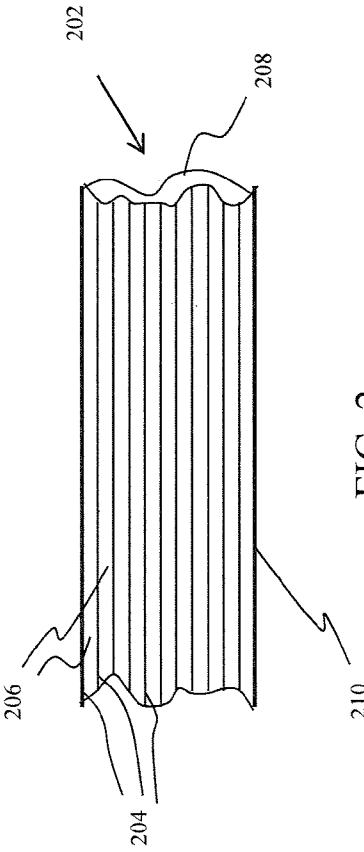

FIG. 2
(PRIOR ART)

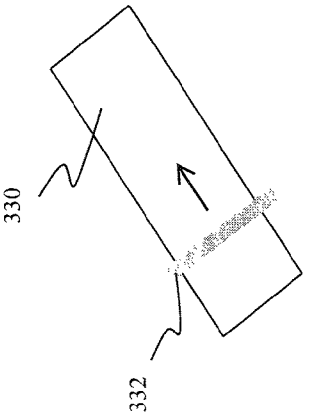

FIG. 3B

FIG. 3A

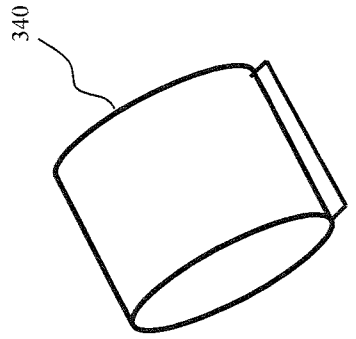

FIG. 4

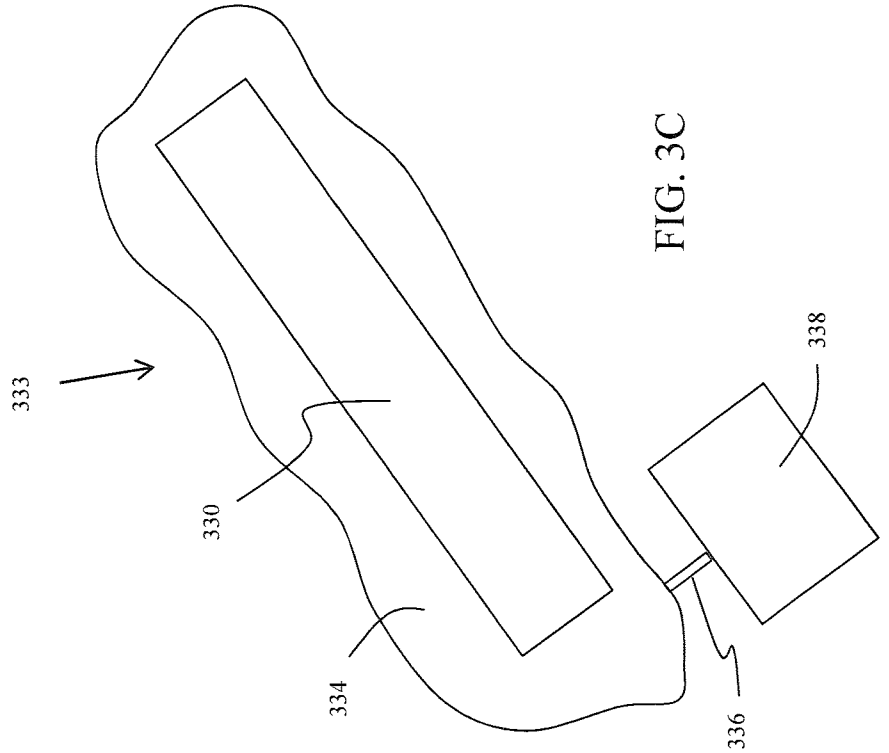

FIG. 3C

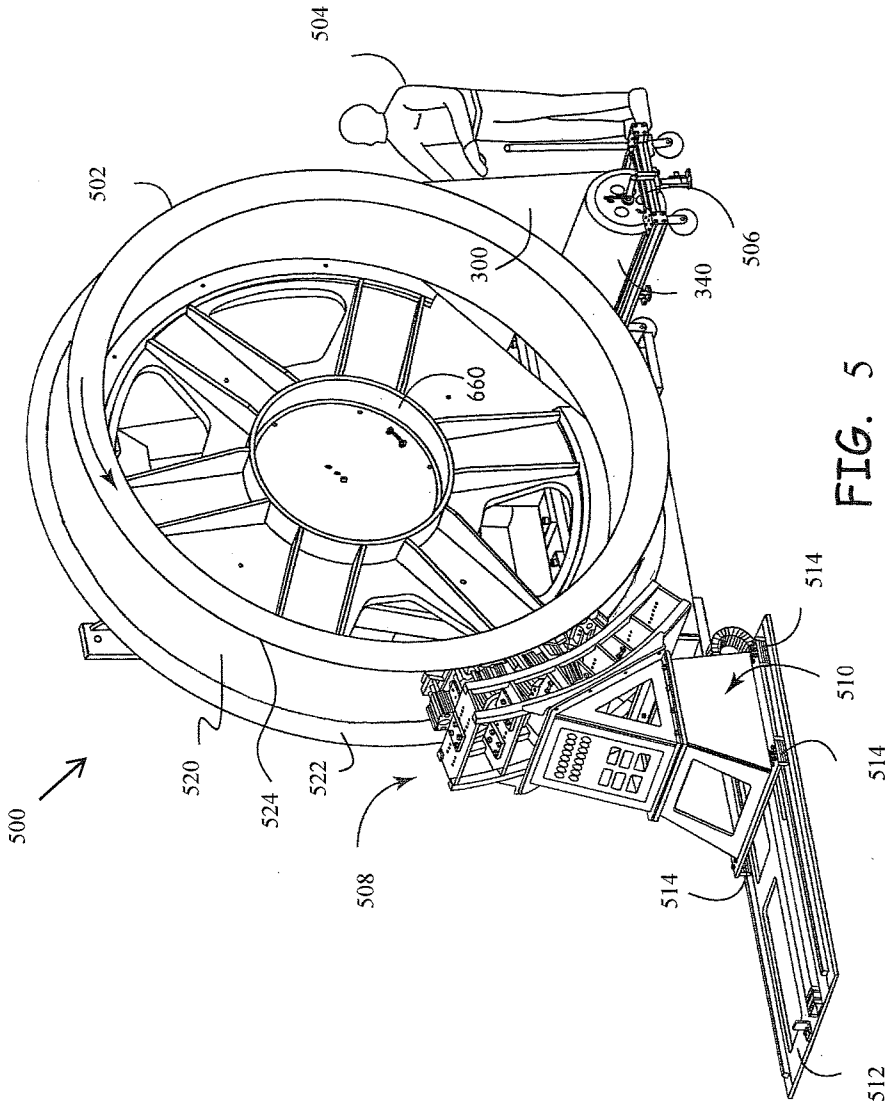

FIG. 5

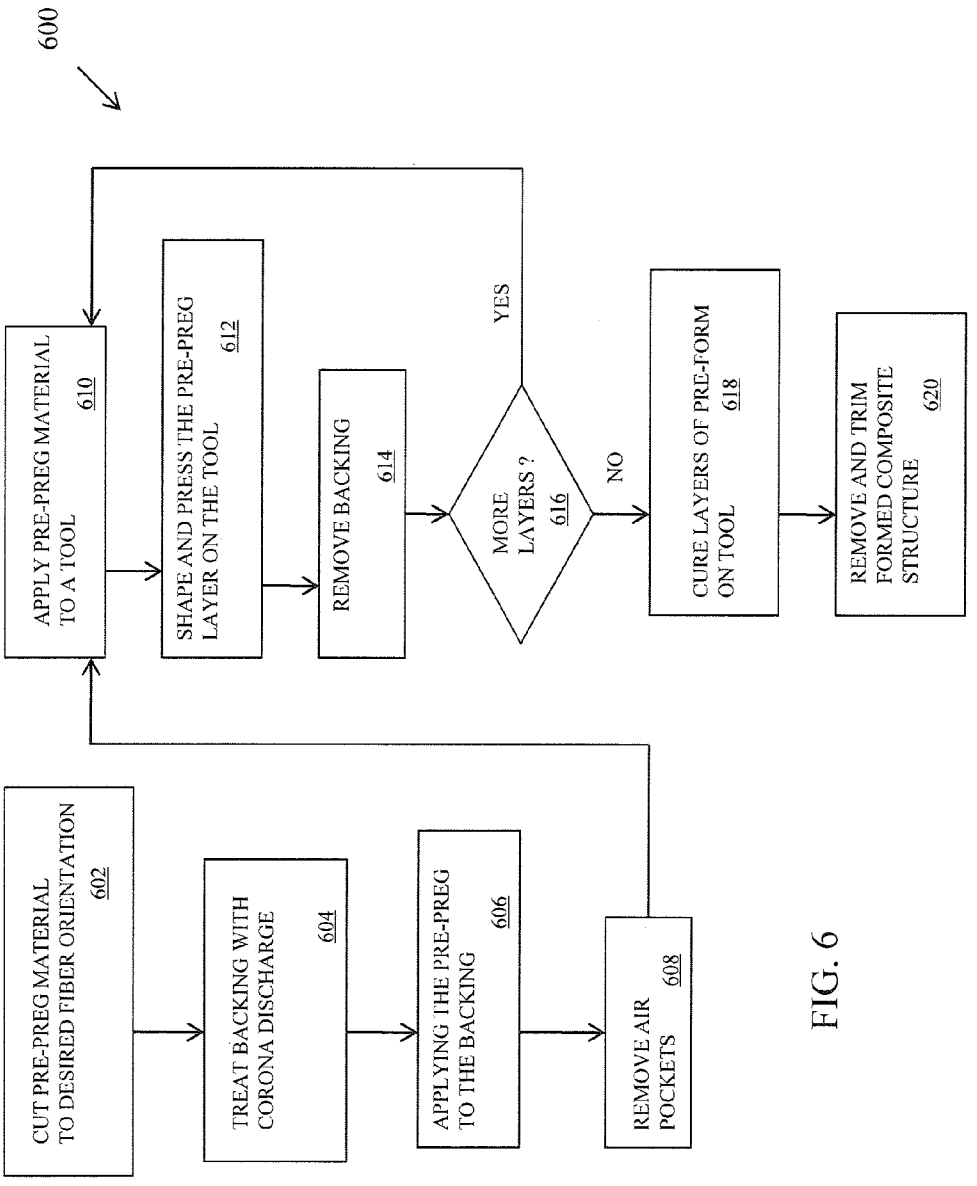
600
CUT PRE-PREG MATERIAL TO DESIRED FIBER ORIENTATION 602
TREAT BACKING WITH CORONA DISCHARGE 604
APPLYING THE PRE-PREG TO THE BACKING 606
REMOVE AIR POCKETS 608
APPLY PRE-PREG MATERIAL TO A TOOL 610
SHAPE AND PRESS THE PRE-PREG LAYER ON THE TOOL 612
REMOVE BACKING 614
MORE LAYERS ? 616
YES
NO
CURE LAYERS OF PRE-FORM ON TOOL 618
REMOVE AND TRIM FORMED COMPOSITE STRUCTURE 620

FIG. 6

BACKING FOR PRE-PREG MATERIAL

BACKGROUND

Pre-impregnated (pre-preg) material is used in the formation of high-strength low-weight structures, such as, but not limited to, parts used to build aircraft and spacecraft. Pre-preg material is made of composite fibers such as carbon, glass, aramid and the like, that are bonded together with a resin that is activated with heat to cure. The pre-preg material is typically formed in sheets that are supplied to the manufacturer of the part. The manufacturer then forms stacks of sheets of pre-prepreg material in a desired shape of the part and heats the part in an autoclave to cure the resin. Sheets of pre-prepreg material are typically supplied in a 0 degree or a 90 degree orientation. That is, the length of the fibers are typically either orientated parallel to a side edge of the sheet or orientated perpendicular to a side edge of the sheet. Some applications require the sheets of pre-preg material having different orientation.

For the reasons stated above and for other reasons stated below that will become apparent to those skilled in the art upon reading and understanding the present specification, there is a need in the art for an efficient, effective and cost effect method of providing a layer pre-preg material having different orientations.

SUMMARY OF INVENTION

The above-mentioned problems of current systems are addressed by embodiments of the present invention and will be understood by reading and studying the following specification. The following summary is made by way of example and not by way of limitation. It is merely provided to aid the reader in understanding some of the aspects of the invention.

In one embodiment, a method of preparing pre-impregnated (pre-preg) material is provided. The method comprises treating a first surface of a backing with a corona discharge to enhance surface adhesion and applying the pre-preg material to the treated surface of the backing to form a pre-preg material with backing.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention can be more easily understood and further advantages and uses thereof more readily apparent, when considered in view of the detailed description and the following figures in which:

FIG. **1** is a side view of a corona discharge system of one embodiment of the present invention;

FIG. **2** is a top view illustration of a pre-preg material of the prior art;

FIG. **3**A is a top view illustration of the forming of the pre-preg material of an embodiment of the present invention;

FIG. **3**B is a top view of an application of a squeegee on a formed pre-preg material with backing;

FIG. **3**C is a top view of an application of a vacuum debulk system on the formed pre-preg material and backing;

FIG. **4** is a side view of a roll of pre-preg material of an embodiment of the present invention;

FIG. **5** is a side perspective view of a forming system implementing an embodiment of the present invention; and

FIG. **6** is a formation flow diagram of one embodiment of the present invention.

In accordance with common practice, the various described features are not drawn to scale but are drawn to emphasize specific features relevant to the present invention. Reference characters denote like elements throughout the figures and the text.

DETAILED DESCRIPTION

In the following detailed description, reference is made to the accompanying drawings, which form a part hereof, and in which is shown by way of illustration specific embodiments in which the invention may be practiced. These embodiments are described in sufficient detail to enable those skilled in the art to practice the invention, and it is to be understood that other embodiments may be utilized and that changes may be made without departing from the spirit and scope of the present invention. The following detailed description is, therefore, not to be taken in a limiting sense, and the scope of the present invention is defined only by the claims and equivalents thereof.

Embodiments of the present invention provide a method of preparing and creating sheets of pre-preg material of select orientations using a corona discharge on a backing material to prepare the backing so the pre-preg material sticks to the backing. Although, this technique works well for various types of backing material such as semi-ridged paper, it also works well for pliable inexpensive polyethylene (PE) backing. The use of a flexible (pliable) backing such as PE is desirable for some applications where the pre-preg is pressed onto a tool with the backing on. This is especially true when applying the pre-preg material around a corner of the tool where the fibers are stretched on the tool to cover the corner. In this situation, the backing also needs to stretch. The use of a paper backing in forming complex shapes can lead to wrinkling or tearing of the backing instead of stretching. As a result, the pre-preg material will fold with the paper or split apart between fibers across the paper tear. Paper backing also allows bridging to occur in concave regions especially if they are adjacent to flat or convex surfaces.

One type of backing material commonly used for pre-preg material is a semi-rigid paper. Paper is a common backing used by pre-preg material suppliers because the pre-preg material sticks well to it. An example of a pre-preg material **202** on a paper backing **208** is illustrated in FIG. **2**. In this example, the pre-preg material **202** includes fibers **204** held together with resin **206**. In this example, the fibers **204** are orientated at a 0 degree angle in relation to a side **210** of the backing material **202**. This 0 degree orientation is a common orientation of pre-preg material provided by pre-preg material suppliers. Pre-preg material supplied by the material supplier can generally be referred to as feedstock. The spacing between the fibers **204** and resin **206** throughout FIGS. **2** and **3**A are provided merely for illustration purposes of orientations. Moreover, the pre-preg material **202** and **300** in FIGS. **2** and **3**A are illustrated as having one layer of fibers orientated in one direction (uni-tape). However, the embodiments also include woven fabric pre-preg material known in the art.

It is often desired to use pre-preg material having different fiber orientations than is provided by the manufacture. Referring to FIG. **3**A, an example of pre-preg material **300** having a desired orientation is provided. In particular, in this embodiment, sections **304***a* through **304***c* of pre-preg material **300** from the material supplier are cut out at a desired angle. The sections **304***a* through **304***c* are then lined up end to end **320***a* to **320***b* and **322***a* to **322***b* and connected together so the fibers **204** have a select angle **306** (orientation) in relation to a side edge **302** of pre-preg material **300**. One method of connecting the section together is with a tape. The sections are then placed on a new backing **108**. As discussed above, it may be

desirable to press the pre-preg material on a tool for forming with the backing material still attached to the pre-preg material. In embodiments, the pre-preg material **300** with the select orientation **306** is placed on a pliable backing **108**. However, pre-preg material **300** will not stick well enough to the pliable backing **108** to prevent it from falling off during forming and handling. Hence, in embodiments, the pre-preg material **300** is placed on a backing **108** surface that has been treated with a corona discharge to promote more adhesion.

Referring to FIG. **1**, a corona discharge system **100** of one embodiment is illustrated. With the corona discharge system **100**, backing **104** from a roll **102** of backing **104** is passed through a corona discharge device **106** to treat one surface of the backing **104**. The corona discharge device **106** exposes the one surface of the backing to an electrical discharge (corona). As a result, oxygen molecules within the electrical discharge area break into their atomic form and are free to bond to the ends of molecules in the backing material. This results in a chemically activated surface that increases surface tension. The treated backing **108** is then rolled up into roll **110** and is ready for use. As discussed above, the backing material in one embodiment is a pliable backing material such as polyethylene (PE). However, the present invention is not limited to PE backing material. In fact, most all types of backing material for pre-preg material can benefit from a corona discharge treatment to enhance bonding of the pre-preg material on the backing. In one embodiment of a PE backing example, a 0.002 inch (2 mil) thick linear low density polyethylene LLDPE film that is treated to a 38+/2 dyne/cm^2 surface energy is used. As discussed above, other types of backing material are contemplated and can benefit from the corona discharge. Different backing material will require different surface energy levels. Moreover, different adhesion levels require different surface energy levels and different thickness of the film used as backing will yield different mechanical behavior in terms of stiffness and conformability. A typical range for a thickness of a backing material would be 0.001 inch to 0.006 inches. Another example type of the elastic material that could be used is polyurethane material. Polyurethane materials are more pliable (elastic) than PE material and offer greater tear resistance and may offer advantages in forming complex shapes. Other types of plastic can be used for backing including, but not limited to, polyester, nylon and fluorinated hydrocarbons. Plasma treating films is another method for increasing surface tension but it tends to burn through thin films.

Once, one surface **108***a* of the backing material **108** has been treated, the pre-preg material **300** is placed on the treated surface **108***a* as illustrated in FIG. **3**A. As stated above, the corona discharge treatment on the treated surface **108***a* of the backing material **108** will adhere to the side edge **302** of the pre-preg material **300**. In one embodiment, entrapped air between the pre-preg material **300** and the treated surface **108***a* of the formed pre-preg material and backing **330** is removed by pushing it out with a squeegee **332** or other wiping method as illustrated in FIG. **3**B. This aids in the adhesion between the pre-preg material **300** and the treated surface **108***a*. In yet another embodiment, a vacuum debulk system **333** is applied to assist pressing the treated surface **108***a* into intimate contact with the pre-preg material **300** and removing air to aid in the adhesion between the pre-preg material **300** and the treated surface **108***a*. An example vacuum debulk system **333** is illustrated in FIG. **3**C. In FIG. **3**C, the formed pre-preg material and backing **330** is placed in a vacuum bag **334** that is connected to a vacuum **338** by a connector **336**. In an embodiment that implements a vacuum debulk, the vacuum debulk is applied at room temperature for as short as 5 seconds. In another embodiment, an elevated temperature of about 45° C. is used in the debulking. Generally, longer vacuum time of higher temperatures help improve the immediate tack. However, the advantages of the higher temperature and time dissipate after 24 hours to the same adhesion value. Adhesion is measured in peel strength. Specimens 75 mm wide are prepared and then pulled tested in a 180 degree peel. Preferred values in one embodiment are in the range of 0.3-0.45 kg/cm width (2-3 lbs/3 inch width). Higher values would tend to stick too well and pull the pre-preg material apart upon removal. Lower values tend to be difficult to achieve with corona discharge of non-slip agent grade of PE or tend not to stick as well through the forming process. Once, the pre-preg material **300** is adhered to treated surface **108***a*, it is ready to be applied to a tool. In one embodiment, once the pre-preg material **300** is adhered to the backing **108** (formed pre-preg material and backing **330**) it is rolled up in a roll **340** that can be easily stored or moved to a desired location for use.

Referring to FIG. **5**, an application of the pre-preg material **300** with the backing **108** treated with corona discharge is illustrated. In particular, FIG. **5** illustrates the pre-preg material **300** being applied by an operator **504** to a tool **502**. The tool **502** in this example rotates about a central hub **660**. The tool **502** in this example includes a first forming surface **520** and side forming surfaces **522** and **524** that form a ring shaped composite structure with opposed flanges. As the tool **502** rotates, the operator **504** applies the pre-preg material **300** from the roll **340** on the forming surfaces **520**, **522** and **524** of the tool **502**. The roll **340** is held by a supply roll holding device **506**. Because the backing **108** has been treated with corona discharged (and vacuum debulked in an embodiment) the backing **108** remains on the pre-preg material **300** even though the pre-preg material **300** is initially shaped by the operator to conform to the shape of the forming surfaces **520**, **522** and **524** of the tool **502** as it is applied.

A forming head **508** that includes a plurality of rollers is used to press the backing **108** and pre-preg material **300** into the forming surfaces **520**, **522** and **524** of the tool **502**. Since, the backing **108** in this example is pliable and treated with the corona discharge, the backing **108** moves as the pre-preg material **300** moves. The forming head **508** in this example is supported by a forming head base **510** that slidably engages a base plate **512** via guides **514**. An example of a forming head **508** arrangement is provided in commonly assigned U.S. patent application Ser. No. 12/615,908 entitled "Automated Composite Annular Structure Forming," filed on Nov. 10, 2009, now U.S. Pat. No. 8,282,757, issued Oct. 9, 2012, which is incorporated herein in its entirety. In one embodiment, once the tool **502** rotates such that a complete layer of pre-preg material **300** and backing **108** has encased the forming surfaces **520**, **522** and **524** of the tool **502**, the pre-preg material **300** and backing **108** are cut. The tool **502** then continues to rotate so that the forming head **508** presses all portions of the backing **108** and the pre-preg material **300** on the forming surfaces **520**, **522** and **524** of the tool **502** while the backing **108**, after contacting the forming head **508**, is removed. Once all the backing **108** is removed, the process is repeated until the desired number of layers of pre-preg material **300** is formed. Once that occurs, the tool **502** with the formed layers of pre-preg material **300** are placed in an autoclave and cured.

FIG. **6** is a formation flow diagram of an embodiment. In this embodiment, the process starts by cutting pre-preg material to a desired fiber orientation (**602**). The pre-preg material may be a uni-tape, woven fabric or the like. A side of a backing of a select material is then treated with corona dis-

charge to increase its adhesion properties (**604**). As discussed above, a variety of different materials could be used for the backing. The pre-preg material having the desired fiber orientation is then applied to the treated surface of the backing (**606**). In one embodiment, air pockets between the pre-preg material and the backing are removed to increase adhesion (**608**). This step may not be needed in all situations. One method used to remove the air is with a squeegee as described. Another method is with a vacuum debulk system. In particular, a vacuum debulking assists in pressing the pre-preg material into the backing and in removing air between pre-preg material and the backing to assist adhesion and performance when the pre-preg is applied to a tool. Once the pre-preg material is coupled to the backing, it can be stored on a roll until use as discussed above or applied to a tool right away.

In using the pre-preg material with corona discharge treated backing, the pre-preg material is applied to the forming surfaces of a tool (**610**). The pre-preg material and backing are then shaped and pressed into the forming surfaces of the tool to form the pre-preg material in a desired shape (**612**). In some embodiments heat is used to aid in the forming of the pre-preg material. Once the pre-preg material has been pressed into the desired shape, the backing is removed (**614**). It is then determined if additional layers of pre-preg material are needed to form the desired structure (**616**). If additional layers are needed (**616**), the process continues at (**610**). If no more layers are needed (**616**), the pre-preg material is cured (**618**). One method of curing the pre-preg material is with an autoclave. Once the pre-preg material has been cured, it is removed from the tool and trimmed to form a composite part (**620**).

Although specific embodiments have been illustrated and described herein, it will be appreciated by those of ordinary skill in the art that any arrangement, which is calculated to achieve the same purpose, may be substituted for the specific embodiments shown. This application is intended to cover any adaptations or variations of the present invention. Therefore, it is manifestly intended that this invention be limited only by the claims and the equivalents thereof.

The invention claimed is:

1. A method of forming a composite structure comprising:
- breaking oxygen molecules into their atomic form with a corona discharge;
- bonding the atomic form of the oxygen molecules to molecules in a first surface of a removable backing material;
- applying a pre-preg material to the first surface of the removable backing material to form a pre-preg material with removable backing, the pre-preg material comprising a curable resin;
- positioning the pre-preg material with removable backing on at least one forming surface of a tool;
- pressing a second surface of the removable backing material of the pre-preg material to apply the pre-preg material on the at least one forming surface of the tool and form the pre-preg material into a desired shape;
- removing the removable backing material from the pre-preg material with removable backing material after the pre-preg material is shaped; and
- curing the pre-preg material.

2. The method of claim **1**, further comprising:
- removing air pockets between the pre-preg material and the removable backing material to enhance adhesion.

3. The method of claim **2**, wherein removing the air pockets further comprises at least one of applying a squeegee and applying a vacuum debulking.

4. The method of claim **1**, further comprising:
- forming the pre-preg material from a feedstock.

5. The method of claim **1**, wherein the pre-preg material is one of a uni-tape and a woven fabric.

6. The method of claim **1**, further comprising:
- vacuum debulking the pre-preg material with removable backing material to enhance adhesion between the pre-preg material and the removable backing material.

7. The method of claim **6**, wherein vacuum debulking the pre-preg material with removable backing comprises applying the vacuum debulking for less than 5 seconds at a temperature of about 45 degrees C.

8. The method of claim **1**, further comprising:
- preparing the pre-preg material to achieve a desired fiber orientation.

9. The method of claim **8**, wherein preparing the pre-preg material to achieve a desired fiber orientation further comprises:
- cutting a feedstock in sections at select angles; and
- coupling the sections of feedstock end to end to form pre-preg material having the desired fiber orientation.

10. The method of claim **1**, wherein pressing a second surface of the removable backing material of the pre-preg material to apply the pre-preg material on the at least one forming surface of the tool and form the pre-preg material into a desired shape further comprises:
- applying forming rollers of a forming head to the second surface of the removable backing material of the pre-preg material with removable backing.

11. The method of claim **1**, further comprising:
- after removing the backing material from the pre-preg material, applying and pressing at least one other layer of pre-preg material before curing.

12. The method of claim **1**, further comprising:
- after curing, removing the formed pre-preg material from the tool; and
- trimming the formed pre-preg material.

13. The method of claim **1**, wherein the removable backing material is made from one of polyethylene, polyurethane, polyester, a paper, nylon and fluorinated hydrocarbons.

14. The method of claim **1**, wherein bonding the atomic form of the oxygen molecules to molecules in a first surface of a removable backing material further comprises applying an energy level to the first surface of the removable backing material, the energy level selected in consideration of an adhesion level between the first surface of the removable backing material and the pre-preg material on the removable backing material.

15. A method of forming a composite structure comprising:
- applying sections of a feedstock comprising a resin and fibers to a removable backing material to form a sheet of pre-preg having a desired fiber orientation relative to a side of the sheet of pre-preg, the desired fiber orientation comprising a non-zero degree angle fiber orientation, and a first surface of the removable backing material bonded to the feedstock through oxygen molecules broken into their atomic form with a corona discharge;
- applying the sheet of pre-preg having the desired fiber orientation to at least one surface of a tool to form a pre-preg having a desired shape;
- removing the removable backing material from the pre-preg having the desired shape; and
- curing the pre-preg having the desired shape.

16. The method of claim **15**, further comprising exposing the removable backing material to a surface energy level selected based on a material used as the removable backing material.

17. The method of claim 15, wherein applying the sections of the feedstock to the removable backing material comprises removing air between the sections of the feedstock and the removable backing material.

18. The method of claim 15, wherein applying the sheet of pre-preg having the desired fiber orientation to at least one surface of a tool to form a pre-preg having a desired shape comprises stretching the sheet of pre-preg having the desired fiber orientation and the removable backing material over the tool.

19. The method of claim 15, wherein applying the sheet of pre-preg having the desired fiber orientation to at least one surface of a tool to form a pre-preg having a desired shape comprises applying the sheet of pre-preg having the desired fiber orientation and removable backing material to the at least one surface of the tool.

20. The method of claim 15, further comprising applying additional sheets of pre-preg having the desired fiber orientation to form the pre-preg having the desired shape.

21. The method of claim 15, wherein the removable backing material is stretchable.

22. The method of claim 15, wherein the removable backing material is pliable.

23. The method of claim 15, wherein the removable backing material is flexible.

24. A method of forming a composite structure comprising:

positioning a sheet of pre-preg material with a removable backing material on at least one forming surface of a tool, the sheet of pre-preg material with the removable backing material comprising sections of a feedstock having a fiber orientation relative to a side of the sheet of pre-preg of a non-zero degree angle fiber orientation applied to a first surface of the removable backing material, the first surface of the removable backing material bonded to the sheet of pre-preg material through oxygen molecules broken into their atomic form with a corona discharge;

forcing the sheet of pre-preg material onto the at least one forming surface of the tool by pressing a second surface of the removable backing material to form the sheet of pre-preg material into a desired shape;

removing the removable backing material from the sheet of pre-preg material after the sheet of pre-preg material is shaped; and

curing the sheet of pre-preg material.

25. The method of claim 24, further comprising selecting the first surface of the removable backing material to exhibit an enhanced surface adhesiveness relative to the second surface of the removable backing material.

26. The method of claim 24, further comprising forcing another sheet of pre-preg material onto the sheet of pre-preg material on the at least one forming surface of the tool by pressing a second surface of another removable backing material of the another sheet of pre-preg material to form the another sheet of pre-preg material into the desired shape.

27. A method of forming a sheet of pre-preg material with a removable backing for a composite structure, the method comprising:

breaking oxygen molecules into their atomic form with a corona discharge;

bonding the atomic form of the oxygen molecules to molecules in a first surface of a removable backing;

orienting a feedstock comprising a resin and fibers at a desired fiber orientation relative to a lateral side of the removable backing comprising a non-zero degree angle fiber orientation;

applying sections of the feedstock to the first surface of the removable backing to form a sheet of pre-preg material including the fibers at the desired fiber orientation relative to the lateral side of the removable backing;

positioning the sheet of pre-preg material on at least one forming surface of a tool;

pressing a second surface of the removable backing to apply the sheet of pre-preg material on the at least one forming surface of the tool and form the sheet of pre-preg material into a desired shape;

removing the removable backing from the sheet of pre-preg material after the sheet of pre-prep material is shaped; and

curing the sheet of pre-preg material.

28. The method of claim 27, further comprising selecting the removable backing to exhibit an enhanced surface adhesion relative to the second surface of the removable backing.

29. A method of forming a composite structure comprising:

applying a pre-preg material to a first surface of a removable backing material to form a pre-preg material with removable backing, the pre-preg material comprising a curable resin, and the first surface of the removable backing material bonded to the pre-preg material through oxygen molecules broken into their atomic form with a corona discharge;

positioning the pre-preg material with removable backing on at least one forming surface of a tool;

pressing a second surface of the removable backing material of the pre-preg material to apply the pre-preg material on the at least one forming surface of the tool and form the pre-preg material into a desired shape;

removing the removable backing material from the pre-preg material with removable backing material after the pre-preg material is shaped; and

curing the pre-preg material.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 8,999,098 B2
APPLICATION NO. : 12/701126
DATED : April 7, 2015
INVENTOR(S) : Peter G. Turner

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the specification:

COLUMN 3, LINE 38, change "0.006 inches." to --0.006 inch.--
COLUMN 4, LINE 63, change "diagram of" to --diagram **600** of--
COLUMN 5, LINE 11, change "between pre-preg" to --between the pre-preg--

In the claims:

CLAIM 27, COLUMN 8, LINE 27, change "of pre-prep" to --of pre-preg--

Signed and Sealed this
Twenty-third Day of February, 2016

Michelle K. Lee

Michelle K. Lee
Director of the United States Patent and Trademark Office